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EVALUATION OF DISTRIBUTED GAS COOLING OF PRESSURIZED PAFC FOR UTILITY POWER GENERATION

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1. EXECUTIVE SUMMARY

The objective of this program is to provide a proof-of-concept test of a gas-cooled pressurized phosphoric acid fuel cell (PAFC). After initial feasibility tests in shorter stacks, two 10-kW stacks will be tested. Progress made in different task areas during the second quarter of the program is summarized below:

Design and Construction of Test Equipment for 12 x 17 in. (1200 cm²) Stack Testing

The design of the test station with a recirculating gas-cooling loop to test 1200 cm² short stacks is complete. Purchase orders for all important subsystem components are also placed. Construction of the test station will soon initiate.

Testing and Evaluation of 5 x 15 in. (350 cm²) Short Stacks

Pressure testing of Stack P5-1 was not possible because all the cells developed irreversible cross-leaks. However, stack P5-2 shows excellent atmospheric performance and pressure testing of this stack will start shortly.

2. TECHNICAL PROGRESS

TASK I. DESIGN AND CONSTRUCTION OF TEST EQUIPMENT FOR 12 X 17 IN. STACK TESTING

Task efforts are being closely coordinated with NASA Contract DEN3-205. Several of the subsystems are similar and therefore are being designed jointly. The design of the long lead time subsystem components have been finalized and the purchase orders have also been placed.

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Construction of the pressurized laboratory and the setting up of facilities will be completed shortly. The overhead crane has been installed. Design details of some of the long-lead time subsystem components are discussed below:

I.1 RECIRCULATION LOOP

The final design of the recirculation loop is completed and is shown in Figure 1. A mass flowmeter (Thermal Instrument, Model 60) with a DC signal output will be used to measure the recirculated gas flow rate in the loop. If need arises in the future, the coolant flow can be controlled by using an electronic controller. A Rotron Aximax 3 blower will be used to recirculate the coolant flow. The speed of the blower motor will be varied by a power supply (Volkman Electric Drives) which will provide a variable frequency output with tracking voltage. The speed control can be either manual or computer set. A butterfly valve will be used to manually close the recirculation flow or to cause some additional pressure drop at lower flow rates to meet blower stability requirements.

I.2 PRESSURE VESSEL

A pressure vessel with a flat plate bottom (favored over the shallow, round bottom configuration because of cost considerations) was designed (see Figure I.2). It will accommodate the 69 x 58 x 35 cm (27 x 23 x 14 in.) fuel cell stack for pressurized operation. The vessel will be made of carbon steel. Only the cell bottom and the flanges will be faced with SS-316. The pressure vessel dimensions and the hole layout are described in Figures I.2 and I.3, respectively. A purchase order has been placed with Norwalk Fabricators of Norwalk, CT for this pressure vessel along with two other condenser vessels. These vessels are expected to be delivered during the month of March 1981.

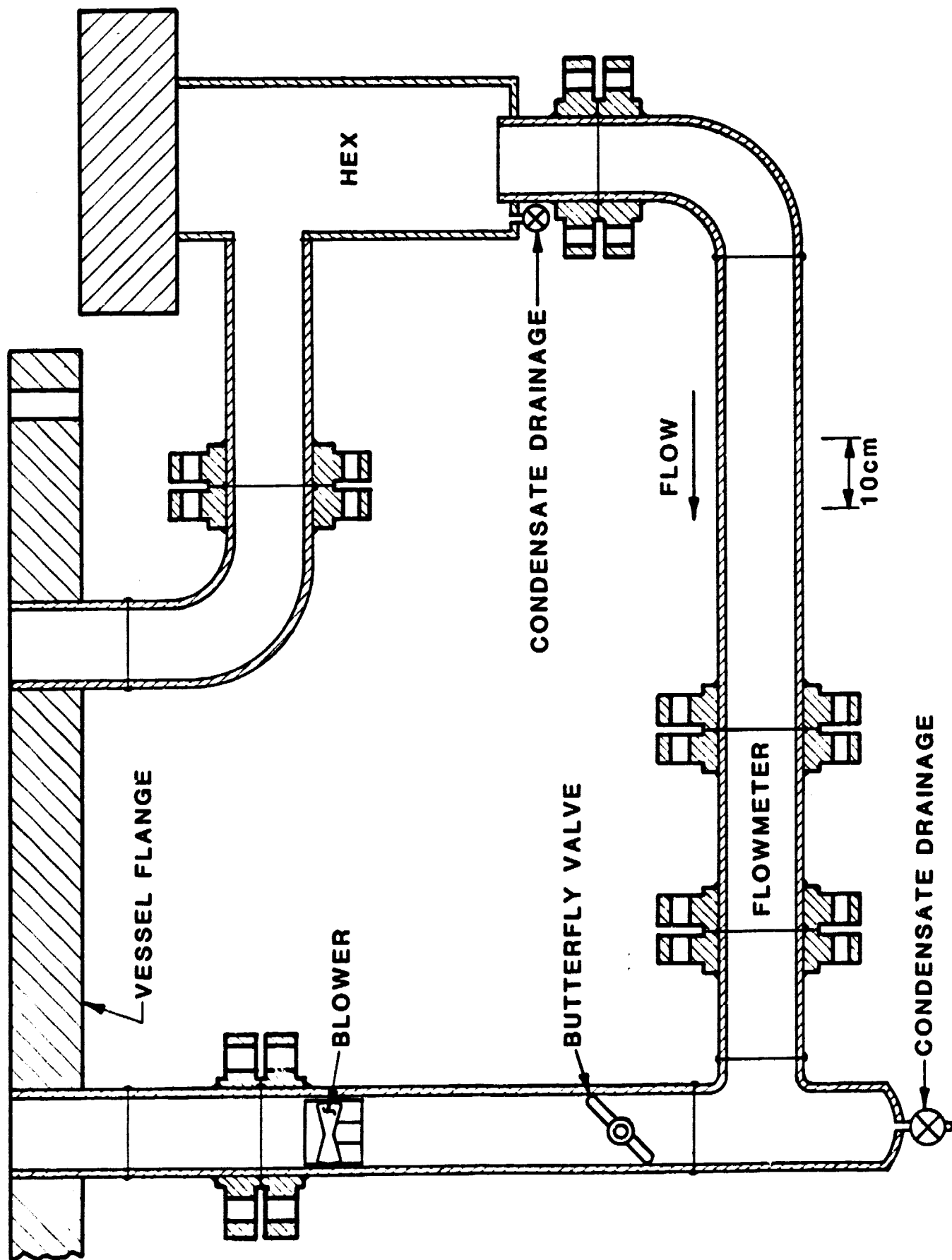
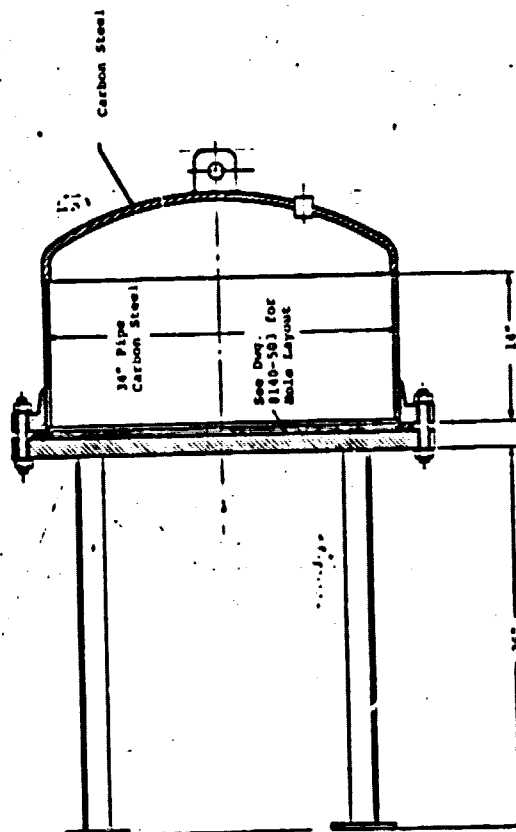


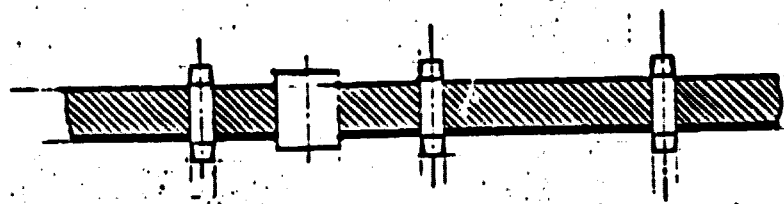
FIGURE I.1. A SCHEMATIC VIEW OF THE RECIRCULATION LOOP



- All welds to be fully radiographed.
- Design Pressure 300 psi (2058 kPa)
- Working Pressure 200 psi (1378 kPa)
- Temperature 177°C

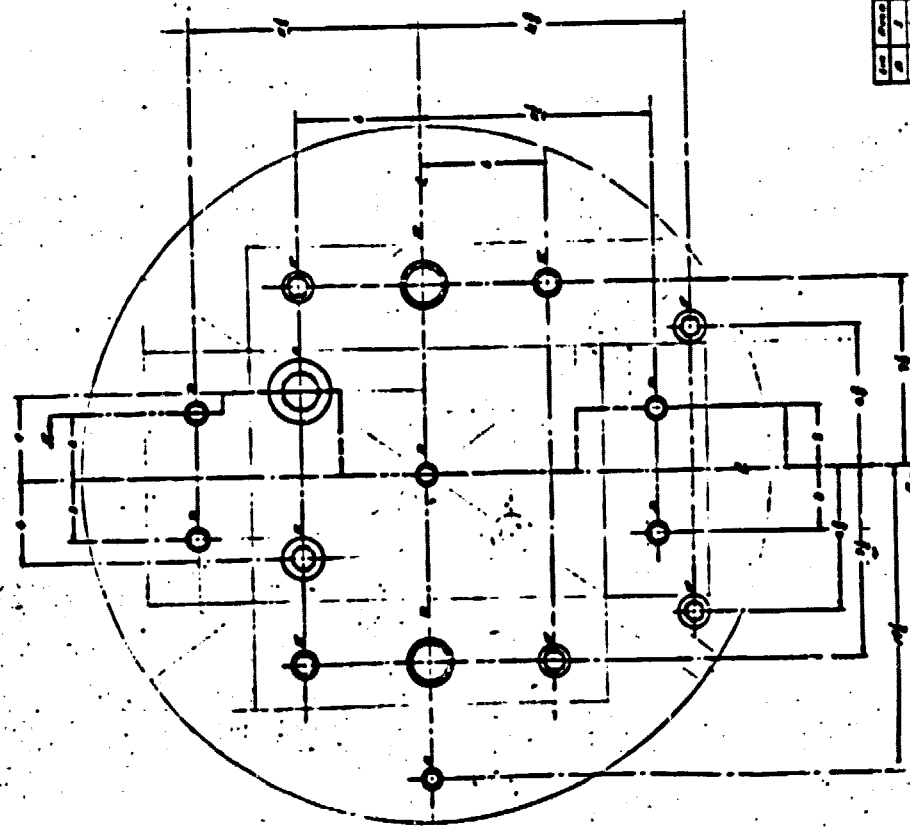
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PAFC PRESSURE VESSEL.



U1438

PAFC Pressure Vessel		After Repair	
Date: 10-10-80		100-000	
By: [Signature]		[Signature]	
Checked: [Signature]		[Signature]	
Approved: [Signature]		[Signature]	



Item	Qty	Part No.	Description
1	1	100-000	PAFC Pressure Vessel
2	1	100-000	After Repair
3	1	100-000	100-000
4	1	100-000	100-000
5	1	100-000	100-000
6	1	100-000	100-000
7	1	100-000	100-000
8	1	100-000	100-000

Figure 1.3 PAFC Pressure Vessel Hole Locations

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I.3 HEAT EXCHANGER

Design of a shell and tube heat exchanger that would remove heat from the fuel cell recirculation loop is also completed. Some design details of the heat exchanger are furnished in Figure I.4. Hot recirculated gas passes through the shell side which has four passes (equipped with 3 baffles). Air has been favored over water as the cooling medium because of control considerations; steam that could form in the coolant water stream might interfere with the operations of the coolant flow control valve. This control valve will interact with the stack temperature controller and will regulate the heat removal rate from the heat exchanger.

Price quotes for this heat exchanger were obtained from different vendors and a purchase order was placed to the lowest bidder.

I.4 DATA ACQUISITION SYSTEM (DAS)

A flow diagram of the DAS to be used for data handling is shown in Figure I.5. The scanner will be responsible for reading the measured variables (current, flow rates, temperatures, voltages, pressure and differential pressures). The microcomputer will record data, control the flow of recirculated stream, and manipulate data. After a detailed examination of the various available data acquisition and control systems, a simple, cost effective system was selected. This system is comprised of a Kaye Instruments' scanner and an Apple II Plus microcomputer. The system uses floppy disks for data storage.

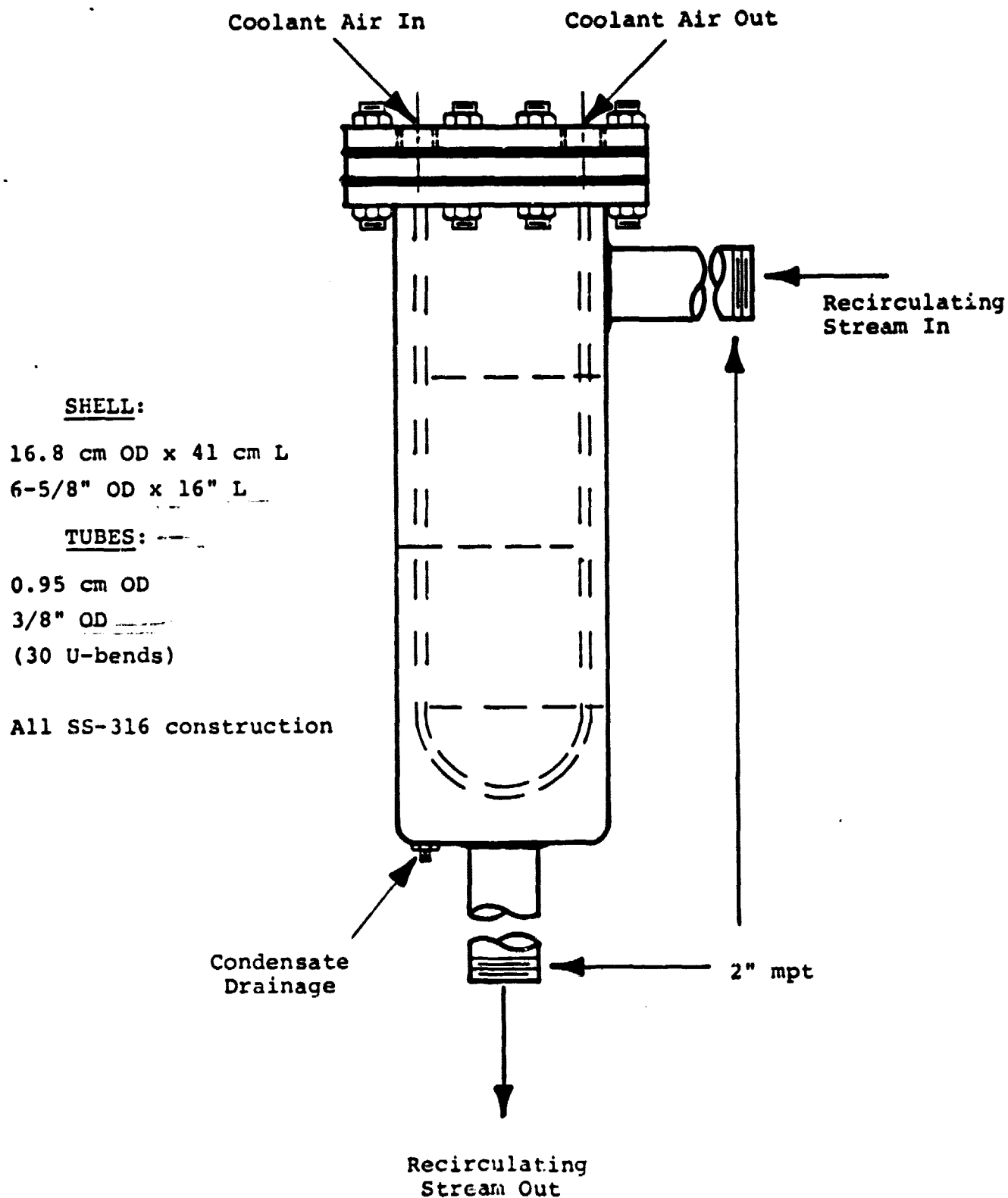


FIGURE I.4 HEAT EXCHANGER

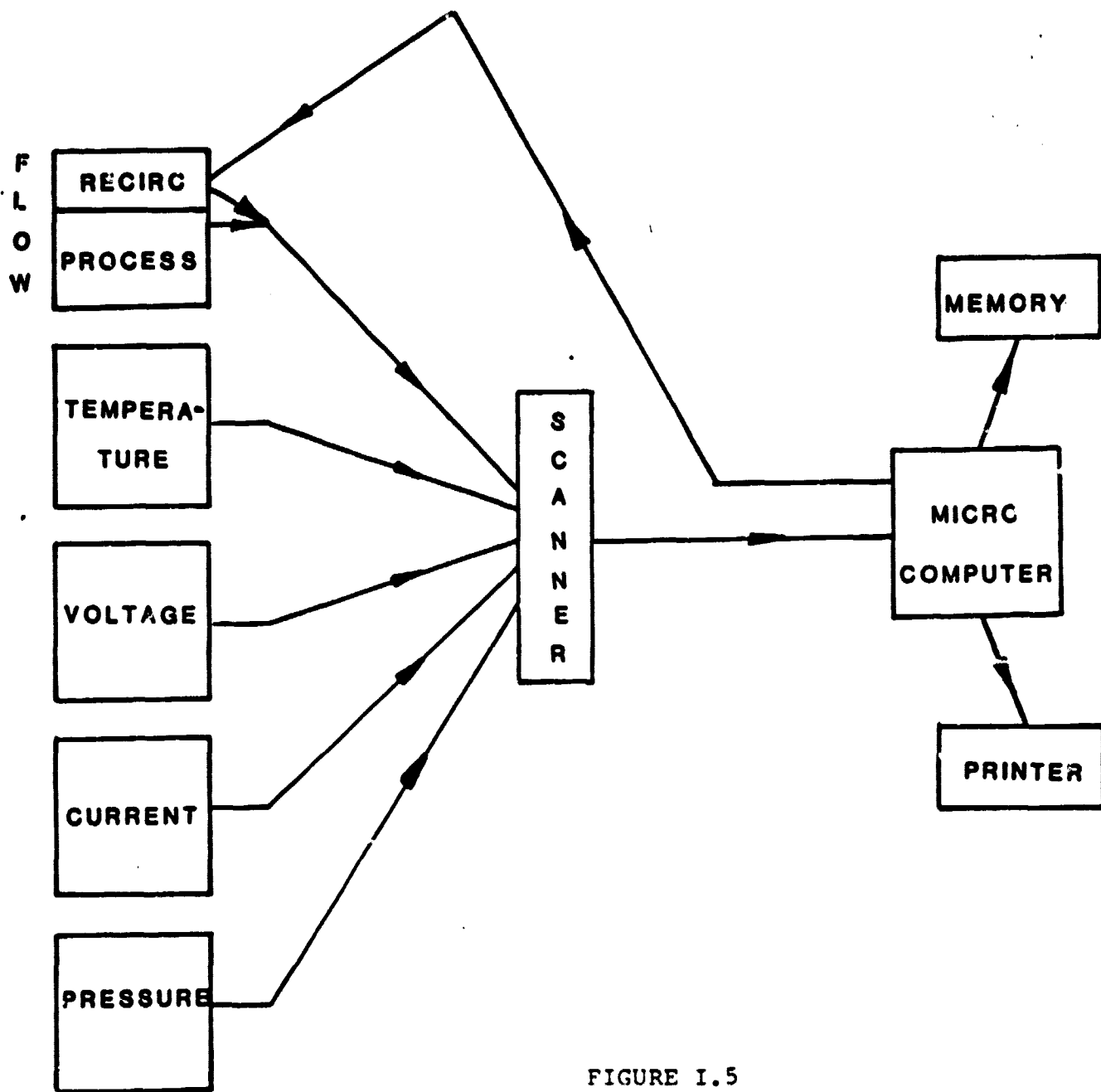


FIGURE I.5
DATA ACQUISITION INFORMATION FLOW DIAGRAM
FOR 12 x 17 in. (1200 cm²) PRESSURIZED TEST FACILITY

D1448A

TASK II. TESTING AND EVALUATION OF 5 x 15 in. (350 cm²) SHORT STACKS

II.1 TEST STAND MODIFICATIONS

The available test stand required some modification to test 6 cell, 350 cm² stacks. All instruments were received inspected and installed. Plumbing modifications were also completed. Anode and cathode lines were successfully leak tested. Unstabilities in the control operation were observed in both the fuel and the oxidant control loop. Problems were traced to a need for larger proportional band width and smaller re-set time in the pneumatic controllers. Two defective synchros also required replacement. Corrective actions are under way and after that stack P5-2 will be pressure tested.

II.2 TESTING OF STACK P5-1

All cells in this stack developed irreversible cross-leaks which could not be arrested by fresh acid additions. After 1600 hours of testing, stack performance dropped an average of 140 mV/cell. This stack was disassembled after 1600 hours of testing for diagnostic post-test inspection. A significant portion of the bipolar plates on the air exit side were found to be wet. Significant electrochemical corrosion was also noticed on the wet portion of the cathode side of the plates. The causes of plate wetting are not well understood at present; further information is required for better insight. However excessive acid in the stack coupled with acid weepage from the acid channels is a potential cause of plate wetting.

As a precautionary measure, a conservative acid addition cycle will be followed in future stacks.

II.3 TESTING OF STACK P5-2

The assembly of Stack P5-2 is completed. The special features of P5-2 which differ from Stack P5-1 are:

- Cooling channel dimensions are 0.43 x 0.27 cm* (compared to cooling plate dimensions of 0.43 x 0.54 cm for Stack P5-1).
- All three cells on one side of the cooling plate are assembled with AICMs (acid inventory control members) Cells on the other side of the cooling plate are assembled with standard anode backing paper. The acid addition channels for these two groups are also separated.
- Stack P5-2 has tantalum shims to prevent blockage at the process gas channel entrance caused by sagging of the backing paper.

Atmospheric testing of the stack has started and the initial performance is summarized in Table II.1.

The initial performance of all cells, including the ones with AICMs, is comparable to the performance of the present ERC state-of-the-art stacks.

The cells with AICMs have low OCVs. The reasons and implications of this observation are not presently known. Further experimental results are required for a better understanding.

Furthermore, excellent oxygen gains, 62mV @ 33% oxidant utilization, and a performance difference of 6mV between 15% CO₂/85% H₂ and 100% H₂ in fuel indicate that the diffusion polarization at both anode and cathode are negligible in all the cells; including the ones with AICM's.

* Dimensions taken before heat-treatment

TABLE II.1
PERFORMANCE OF STACK P5-2

CELL NO.	PERFORMANCE*, V	
	After 95 hours	OCV
1 } uses	0.68	0.83
2 } AICMs	0.67	0.80
3 }	0.68	0.80
4	0.67	0.85
5	0.68	0.86
6	0.67	0.89
TOTAL	4.05	5.03

- * At atmospheric conditions, at 100 mA/cm²
 Stack resistance: 6 m Ω
 Air temperature: 108°C (in), 181°C (out)
 H₂ temperature: 118°C (in), 156°C (out)
 Stack temperature: 183°C
 Air flow rate: 33 lpm (9 stoich, 2 stoich thru process channel)
 H₂ flow rate: 1.5 lpm (80% H₂ utilization)

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A lifegraph of the stack (Figure II.1) P5-2, representing the first 750 hours indicate that the performance of this stack is also quite stable with time. Shortly this stack will be pressure tested.

3. PROBLEMS

Control unstabilities observed in Task II are discussed in the main text. Crossleak problems were encountered in Stack P5-1 as described in the text under "Technical Progress". Apparently the crossleak is associated with some damage caused during back-pressure testing. A more conservative testing procedure will be used in future experiments.

4. PLANS

TASK I.

- Station assembly

TASK II.

- Pressure testing of stack P5-2, P5-3, and P5-4.
- Establishment of baseline pressurized performance data, start up/shut down procedures and temperature profiles.

TASK III.

- Completion of design of Stack P12-1.

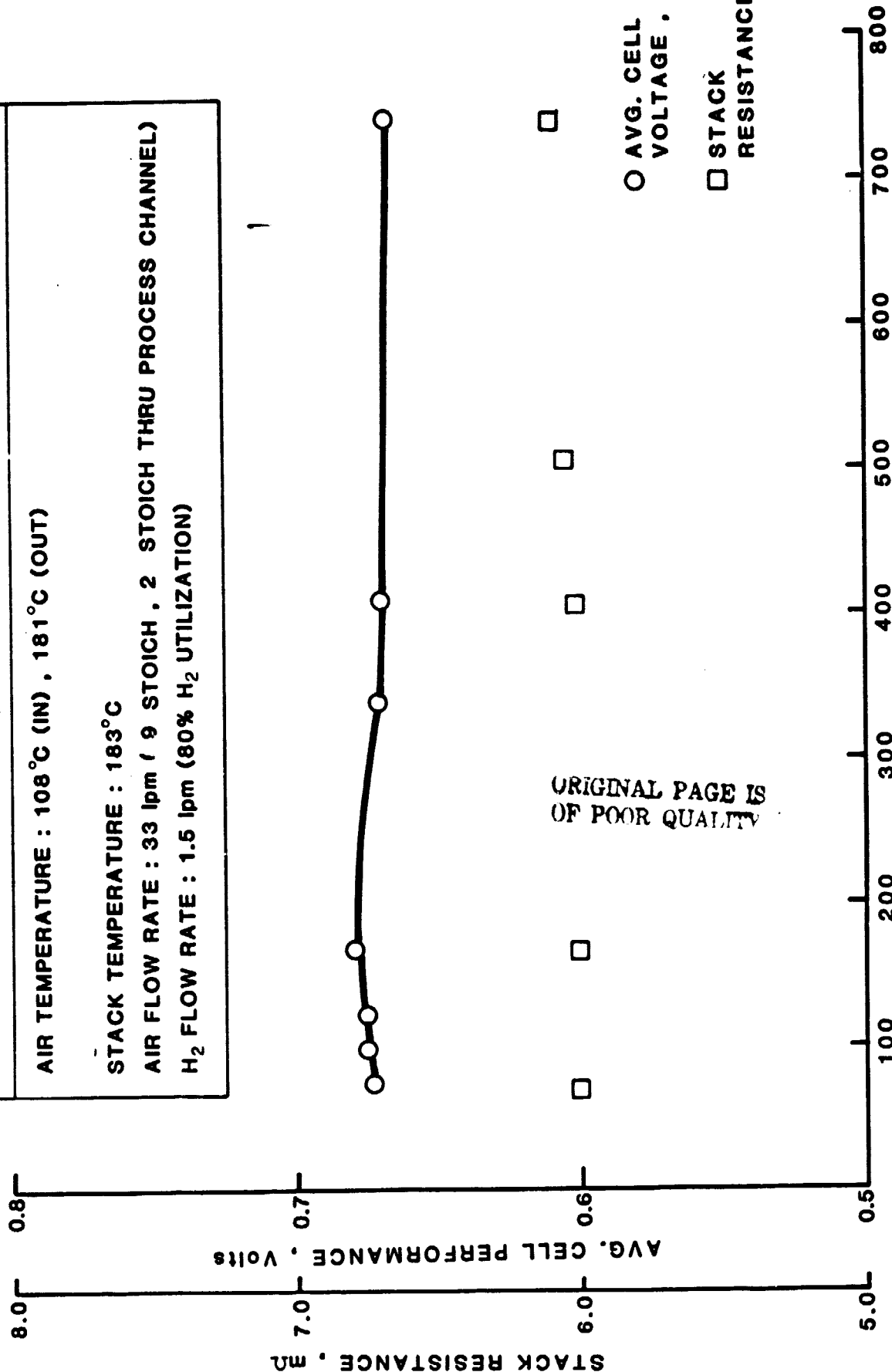
AT ATMOSPHERIC CONDITIONS, AT 100mA/cm²

AIR TEMPERATURE : 108°C (IN) , 181°C (OUT)

STACK TEMPERATURE : 183°C

AIR FLOW RATE : 33 lpm (9 STOICH , 2 STOICH THRU PROCESS CHANNEL)

H₂ FLOW RATE : 1.5 lpm (80% H₂ UTILIZATION)



STACK LIFE , Hrs.

FIGURE II.1: LIFEGRAPH OF STACK P5-2